Grass growth model evaluation to manage grass supply on farm in the south of Ireland

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Abstract

Meteorological conditions, as well as management factors, influence grass growth. Grass growth is highly seasonal in Ireland with little growth over the winter period due to low temperatures and low levels of sunshine. Peak grass growth occurs in late spring and early summer, and in the late summer and autumn growth is restricted as temperature and solar radiation decline. As a result of variation in grass growth within and between years, grass budgeting at farm level is challenging. The objective of the study was to evaluate three grass growth models for use in Ireland ("Johnson and Thornley"; "Jouven"; "Brereton") using measured grass growth data at Teagasc Moorepark over a 5 year period (2005-2009). For the model evaluation of predicted versus measured grass growth, the mean square prediction error (MSPE) was used. The Johnson and Thornley model over-predicted grass growth in all years, with a high primary grass growth peak and a high mean bias. The Jouven and Brereton models predicted grass growth closest to that measured as indicated by their line bias. The models with the greatest potential for grass growth prediction in Ireland, albeit with some modifications, are the Jouven and Brereton models.

Keywords: grass growth models, manage grass supply, feed prediction

Introduction

Meteorological conditions, as well as management factors, influence grass growth. As a consequence, there are marked seasonal variations in herbage production, both within and between years, mainly due to meteorological factors, as well as soil conditions and management factors such as fertilizer application, grazing intensity and rotation length. Grass can provide more than 70% of the diet of dairy cows in Ireland (Dillon et al., 2005). Grass growth is highly seasonal in Ireland with little growth over the winter period due to low temperatures and low levels of sunshine. Peak grass growth occurs in late spring and early summer, and in the late summer and autumn growth is restricted as temperature and solar radiation decline. As a result of variation in grass growth within and between years, grass budgeting at farm level is challenging. There is a need for model development for grass growth prediction to forecast grass growth accurately, allowing better management around the variability of feed supply. The development of such a model would help identify feed surpluses and deficits, and therefore increase the accuracy of management decisions on farm.

The objective of the study was to evaluate three existing grass growth models for use in Ireland ("Johnson and Thornley"; "Jouven"; "Brereton") using measured grass growth data at Teagasc Moorepark over a 5 year period (2005-2009).

Material and methods

Models

Three models were selected, the English model developed by Johnson and Thornley (1983) (J&T model), the French model developed by Jouven *et al*. (2006) (J model) and the Irish model developed by Brereton et al. (1996) (B model). The J&T model is mechanistic and dynamic, and is used to simulate the time course of dry matter (DM) and leaf area development in a daily time step. The J model is a mechanistic dynamic model developed to investigate seasonal and annual interactions between grassland dynamics and management. The originality of the J model lies in the combination of two approaches: functional and structural. The B model was initially developed as a static and empirical model to evaluate the differences in herbage production of grazing systems between years, depending on the effects of weather conditions. It does not explain the nature of grass growth but provides an explanation of the dynamics of a grazing management system subject to a variable feed supply.

Meteorological and grass growth data

Daily meteorological data was available from Moorepark (latitude 50°07′N, 8°16′W; 46masl) for the years 2005–9, inclusive. The meteorological data required as an input to the models includes rainfall (mm), minimum and maximum air temperatures (°C), wind speed (m/s), sunlight hours (h) and solar radiation (J/cm^2/day). Soil moisture deficit (SMD), required as an input for the B model, was calculated using the hybrid SMD model described by Schulte et al. (2005). This model was also used to calculate potential evapotranspiration (ET) required as an input for the J model. Sunshine hours were converted from solar radiation using the method described by Smith (1967) and used as an input for the J&T model.

Weekly grass growth data were measured at Moorepark for the period 2005–9. Grass growth was measured using the methodology described by Corral & Fenlon (1978), which estimates grass growth on a 4-week harvest interval. This approach was mimicked by the models in the present study. This involved four start dates for each model. Herbage mass was accumulated over the 4-week period and then harvested. A quadratic approximation was then applied to this data to calculate total herbage production for the 4-week period, and is then divided by 28 to give daily grass growth.

Model evaluation

The three models were simulated over the period 2005–9. Herbage production was modelled for each year separately. Modeled herbage production was compared with recorded herbage production over the 2005–9 period. For the model evaluation of predicted versus measured grass growth, the mean square prediction error (MSPE) was used.

Formattato: Inglese (Regno Unito)

Eliminato: Modelled

The MSPE is the sum of three components: the mean bias $(M_m - P_m)^2$, the line bias $S_P^2 (1 - b)^2$ and the random variation about the line $S_M^2 (1 - R^2)$. Each is expressed as a proportion of the total MSPE (Eqn 1).

$$MSPE = {}^{1}/_{n} \sum (M - P)^2 = (M_m - P_m)^2 + S_P^2 (1 - b)^2 + S_M^2 (1 - R^2) \quad (1)$$

where n is the number of measured and predicted pairs compared, M_m and P_m are the means of M and P, respectively, S_P^2 and S_M^2 are the variances of M and P, respectively, b is the slope of the line of P regressed on M, and R^2 is the determination coefficient of the line.

Results

The average annual total herbage production at Moorepark for the period 2005–9 was 14087 kg DM/ha (Fig. 1), with an average grass growth of 50.3 kg DM/ha/day. The J&T model over-predicted grass growth in all years, this being most apparent from mid-April to late-summer, by a mean of 88.9 kg DM/ha/day, with a high primary peak and a high mean bias (Table 1). The J&T model failed to predict the large drop in grass growth due to drought conditions that occurred in 2006. The J model under predicted grass production by 13.9 kg DM/ha/day. The J model mostly under-predicted grass growth for the spring period, but it closely followed the trends for the remainder of the year, except in 2008, where it only predicted the primary peak A good prediction slope was observed for the J model (line bias 0.089) and the random variation was 0.560 (Table 1). The B model over-predicted grass production with a grass growth over-prediction of 8.3 kg DM/ha/day. The B model over predicted grass growth during the early spring and late autumn periods, but it followed closely the observed trend during the mid-season with the exception of 2007, where it only predicted the secondary peak. Most of the variation in the grass production predicted by the B model was due to random variation (0.73), and overall, a small line bias was observed (0.09; Table 1). In 2006, a year with a high SMD in mid-summer, the B model had the best fit, with the lowest MSPE.

Discussion

None of the models worked perfectly under the conditions of the study. A suitable model for use as a grassland management tool requires greater accuracy than that available from the three models evaluated. Further site-specific calibration may be needed to improve grass growth predictions of the models. A suitable model must be as precise as possible, be dynamic, use realistic input parameters, incorporate meteorological data and explain the physiology of grass growth. Budgeting grass supply allows producers to minimize the quantity of purchased feed and silage required in the diet. Increasing food demand and pressures from climate change will force farmers to be dynamic in the decision-making process and so accurate prediction of grass growth will allow strategic planning of the feed budget.

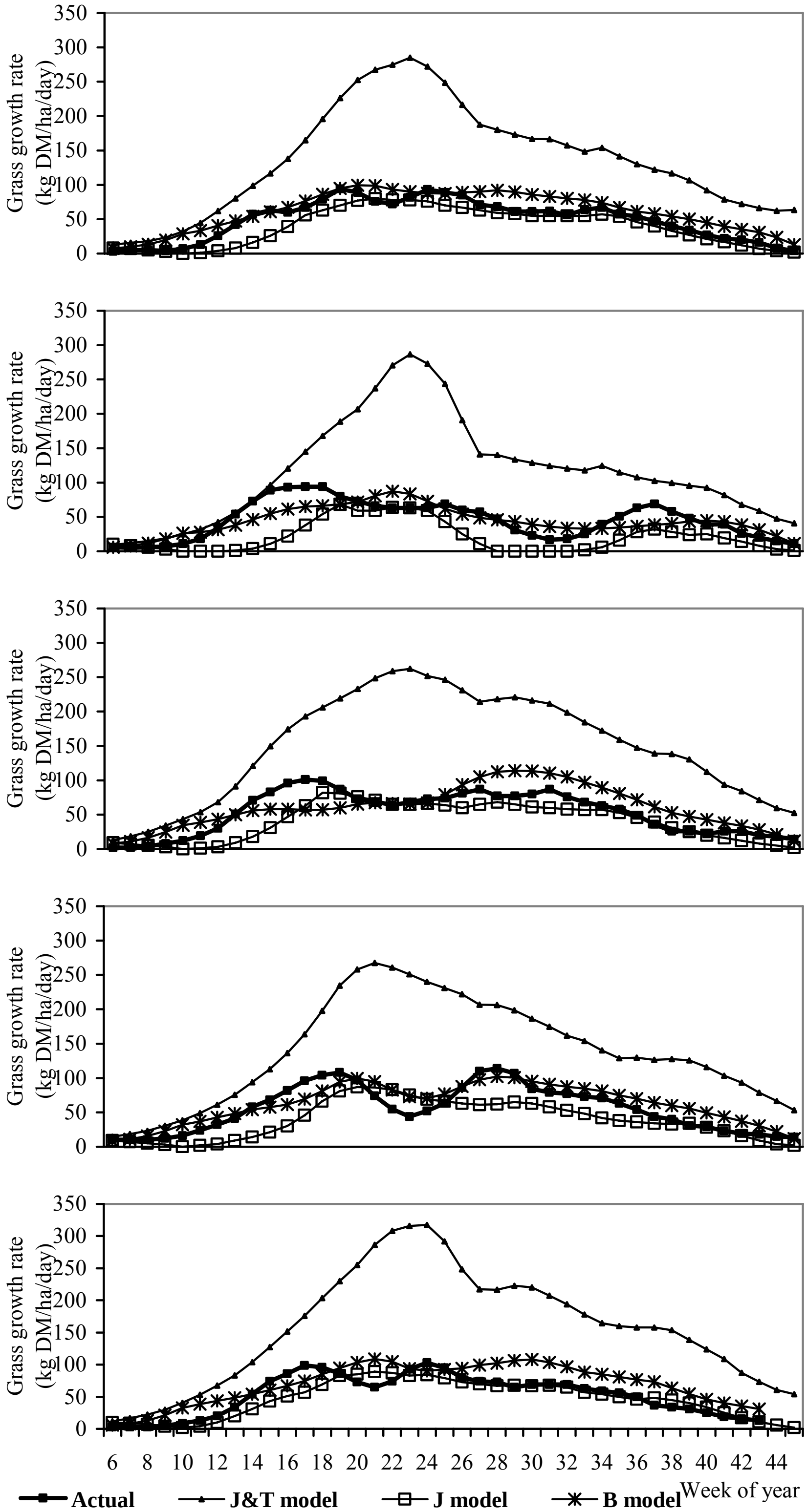
Conclusion

The models with the greatest potential for grass growth prediction in Ireland, albeit with some modifications, are the Jouven and Brereton models.

Table 1. Precision of simulation of grass growth by the three models: Johnson & Thornley (1983) (J&T model), Jouven et al. (2006) (J model) and Brereton et al. (1996) (B model) using MSPE (kg DM/ha/day) for 2005–09, 2005, 2006, 2007, 2008 and 2009. Proportions of MSPE may not always sum to 1·00 due to rounding.

Eliminato: *for 2005*

Period	**Models**	**Proportion of MSPE**			**MSPE**	R^2
		Mean bias	**Line bias**	**Random**		
2005–09	J&T model	0.488	0.493	0.019	16309	0.66
	J model	0.350	0.089	0.560	559	0.66
	B model	0.181	0.090	0.730	373	0.70
2005	J&T model	0.338	0.657	0.005	22398	0.87
	J model	0.452	0.047	0.501	219	0.87
	B model	0.668	0.015	0.317	219	0.92
2006	J&T model	0.595	0.351	0.054	8448	0.39
	J model	0.548	0.090	0.362	1135	0.45
	B model	0.011	0.199	0.791	334	0.65
2007	J&T model	0.526	0.460	0.014	17714	0.75
	J model	0.381	0.089	0.529	459	0.75
	B model	0.118	0.110	0.772	506	0.59
2008	J&T model	0.664	0.294	0.043	10574	0.59
	J model	0.346	0.115	0.539	808	0.60
	B model	0.166	0.145	0.689	280	0.82
2009	J&T model	0.427	0.564	0.009	27705	0.76
	J model	0.088	0.130	0.782	250	0.80
	B model	0.484	0.043	0.473	580	0.73



Grass growth rate (kg DM/ha/day)
350
300
250
200
150
100
50
0
6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Week of year
Actual
J&T model
J model
B model

Figure 1. Predicted and measured grass growth data (kg DM/ha/day) for weeks 6 to 45 for the 5 years 2005 to 2009 at Moorepark. Grass growth was predicted using Johnson and Thornley (1983) Model (J&T model), Jouven et al. (2006) Model (J model) and Brereton et al. (1996) Model (B model). Grass growth was measured at Moorepark using the methods described by Corral and Fenlon (1978).

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